

Stator Winding Fault Identification in Three Phase Induction Machine by Using Motor Current Signature Analysis

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ABSTRACT: Induction motors are one of the commonly used electrical machines in industries. If any fault occurs in these machineries then the entire operation in progress will go vain. Among the Induction motor faults, stator winding fault is a common and severe problem. It should be detected in its initial stage in-order to prevent the complete failure of the motor and unexpected production costs. This paper proposes a condition based monitoring technique of motor where the stator short-circuit fault is analyzed. The short-circuit fault includes phase to phase short and phase to ground short. The method used to detect the fault is based on Motor Current Signature Analysis. It includes stator current monitoring as it is a non-intrusive method and its spectrum helps in locating characteristic fault frequencies. The proposed concept is simulated and results where verified using MATLAB software.

KEYWORDS: Induction Motor, Stator Winding, Fault, Motor Current Signature Analysis.

I. INTRODUCTION

The studies of induction motor behaviour during abnormal conditions due to presence of faults and the possibility to detect these abnormal conditions have been a challenging topic for many electrical machine researchers. There are many condition monitoring methods including vibration monitoring, thermal monitoring, chemical monitoring, acoustic emission monitoring but all these monitoring methods require expensive sensors or specialized tools whereas current monitoring out of all does not require additional sensors. This is because the basic electrical quantities associated with electromechanical plants such as current and voltage are readily measured by tapping into the existing voltage and current transformers that are always installed as part of the protection system. As a result, current monitoring is non-intrusive and may even be implemented in the motor control centre remotely from the motors being monitored.

It is observed that the technique called 'Motor Current Signature Analysis' (MCSA) is based on current monitoring of induction motor; therefore it is not very expensive. The MCSA uses the current spectrum of the machine for locating characteristic fault frequencies. When a fault is present, the frequency spectrum of the line current becomes different from healthy motor. Such a fault modulates the air-gap and produces rotating frequency harmonics in the self and mutual inductances of the machine. It depends upon locating specific harmonic component in the line current. Therefore, it offers significant implementation and economic benefits. In the proposed work, Motor Current Signature Analysis (MCSA) based methods are used to detect the short circuit fault of induction motor. The effects of various short circuit faults on current spectrum of an induction motor are analyzed through simulation. The main causes for stator winding fault are listed in Table.1.

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Table.1 Types of stator winding fault

Type	Causes
Inter-turn short circuit	Excessive temperature, high humidity, vibration, over voltage.
Inter-phase short circuit	Insulation failure, high temperature, imbalanced supply, slacking of coils.

According to surveys, stator winding faults account for 30 - 40% of all electrical failures. Stator winding faults can either be turn-to-turn (short circuit within the same phase) or other phase combinations (phase-to-phase, phase to ground and or three phase faults). Section II describes the motor current signature analysis for the identification of stator winding fault, Detection methodology along with simulated results is given in Section III. Finally, Section IV presents conclusion.

II. RELATED WORK

Condition monitoring of motor is important to detect the fault while they are developing. This is called incipient failure detection. It provides safe operating environment. By using this technique, it is possible to provide adequate warning of imminent failure. In addition, it is also possible to schedule future preventive maintenance and repair work. Therefore effective condition monitoring to detect the fault improves reliability, safety and productivity. The condition monitoring techniques include Thermal monitoring, Vibration monitoring, Electrical monitoring, Noise monitoring, Torque monitoring and Flux monitoring. In this chapter Electrical monitoring to detect the fault is discussed.

The electrical monitoring is based on analysing the stator current of the induction motor. Motor Current Signature Analysis technique is a popular method for monitoring the stator current to detect the faults. MCSA technique has many advantages. It is non-invasive, where stator current is measured simply by using current transformers (CT) and no other special equipment is needed. By simply processing the motor current signals, numerous faults can be detected: damaged rotor bar, such as, broken rotor bars, static or dynamic eccentricities due to unbalanced rotor, bearing defects, stator winding shorted.

The Stator-current spectrum signature of healthy cage rotor induction machines, classifies the harmonics present in the healthy induction machines. This is a starting point for diagnosis of faults using motor current signature analysis[1]. A review of induction motors signature analysis as a medium for faults detection was done in [2] and it gives the details about motor signature analysis for the detection and the localization of abnormal electrical and mechanical conditions of the motor. It may lead to a failure of induction motors. This analysis utilized the results of spectral analysis of the stator current to detect the fault. In [3] aberrant analysis of three phase induction machine with stator inter turn faults on windings was done to estimate the transient performance of the motor with faults. Also, the effects of the stator inter turn faults of the induction machine with different turns shorted were investigated in this article. The importance of induction motor in field application and need of fault detection and classification techniques for internal and external fault non-invasive detection was reviewed in [4]. In [5] transient and steady state analyses of a healthy motor and motor under stator, rotor, and mixed faults by using non-invasive fault diagnosis technique was illustrated. Monitoring and Fault detection of the Stator short circuit fault in induction motor based on the Fuzzy Logic approach was investigated in several articles. A fuzzy logic control method used to interpret the stator current signal of induction motor for identifying motor condition shows good result and capable to identify the correct fault in the winding of the motor[6-10]. Eltabach, Mario in his article investigated the induction motor fault by spectral principal components analysis of the supply currents. This new diagnostic procedure used only the three motor supply currents. The theoretical principles directly related to the application focus on extracting pertinent information from spectral matrices.

As such, condition of a machine can be monitored and detected at a remote location, which may be located in a hazardous environment or inaccessible location, and the machine does not need to be physically disassembled for diagnosis where individual parts are inspected for signs of faults. Motor current is highly sensitive to changes in the magnetic flux of the machine. The changes due to machine faults, induces harmonics in the motor current. Therefore, prognosis of incipient fault is also made possible by MCSA. This way fault is pre-empted and spare parts ordered well

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in advance before the actual faults develop, and allows for speedy repairs and shortened shutdown time. These advantages have greatly motivated researches in MCSA.

The stator short circuit fault does not affect the normal operation in the early stage; it will reduce the efficiency of a motor and even damage it when the fault becomes severe. Therefore, early detection of the stator short circuit fault in operation is important before it becomes a catastrophic failure to induction motors. In addition, it will help to eliminate costly damages in terms of loss of production time and avoid expensive cost for maintenance and repair.

The detection of stator winding fault in stator windings of an induction motor using the motor current signature analysis (MCSA) is based on detecting the frequency components given by equation

$$f_{\text{short}} = f_s [k \pm n/p(1-s)] \quad (1)$$

where,

- f_{short} is the frequency component that is a function of the short circuit,
- f_s is the supply frequency,
- p is the number of pole pairs,
- n and k are two parameters, $n = 1, 2, 3, \dots$ and $k = 1, 2, 3, \dots$

The slip speed s is defined as

$$s = (\omega_{\text{sm}} - \omega_{\text{rm}}) / \omega_{\text{sm}} \quad (2)$$

where $\omega_{\text{sm}} = (2\omega_e)/p$ the synchronous speed in mechanical radians, ω_e is angular speed of the stator Magnetic Motive Force (MMF) in electrical radians per second and ω_{rm} is the rotor rotating speed. When $k = 1$ in equation(1), the component frequency, induced in the spectrum of the stator current, superimposed on the fundamental current, will be illustrated by the following formula

$$f_{\text{comp}} = f_s [n/p(1-s)] \quad (3)$$

For two pole motors ($p = 2$) in first instance, the equation (3) will be a whole series of components:

$$\begin{aligned} f_{\text{comp}} = & f_s (1-s), n=1 \\ & 2f_s (1-s), n=2 \\ & 3f_s (1-s), n=3 \end{aligned} \quad (4)$$

For four pole motors ($p = 4$), the equation (3) will be revealed by the following series of components:

$$\begin{aligned} f_{\text{comp}} = & (1/2)f_s (1-s), n=1 \\ & f_s (1-s), n=2 \\ & (3/2)f_s (1-s), n=3 \end{aligned} \quad (5)$$

These components are visible in the frequency spectrum of the stator current (as side-bands to the fundamental peak) as shown in Fig.1. With the help of these characteristic, faults are detected.

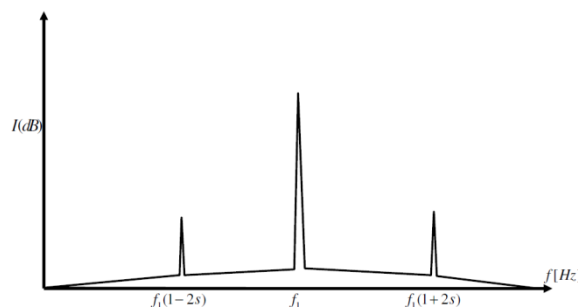


Fig.1: Idealized current spectrum

III. DETECTION OF STATOR WINDING FAULT USING MOTOR CURRENT SIGNATURE ANALYSIS

To detect the short circuit fault using motor current signature analysis stator current spectrum is needed. It is obtained by using Fast Fourier Transform (FFT) of stator current signal. The process involved in spectrum analysis is shown in Fig.2.

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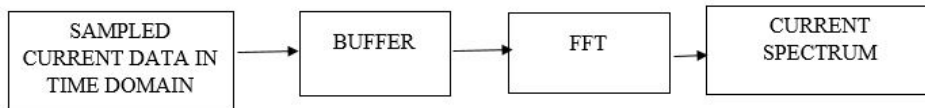


Fig.2. Blocks for determining current spectrum

The simulation was done by using MATLAB software and the simulation diagram to detect the short circuit fault using motor current signature analysis is shown in Fig.3.

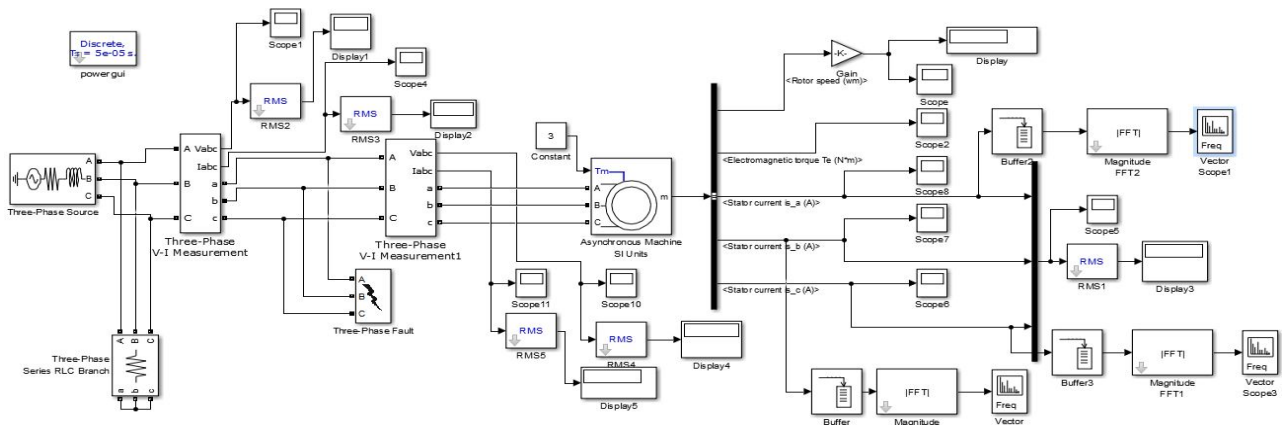


Fig.3. Simulation of fault identification of Induction Motor using MCSA

The current amplitude (dB) of phase A, phase B, phase C at fundamental (50 Hz), lower side band (30 Hz) and upper side band (70Hz) frequency during phase-phase fault at full load conditions are tabulated in Table 2.

Table 2 Current amplitude in dB during phase - phase fault

FREQUENCY (HZ)	PHASE A – PHASE B FAULT			PHASE B – PHASE C FAULT			PHASE C – PHASE A FAULT		
	I _a	I _b	I _c	I _a	I _b	I _c	I _a	I _b	I _c
30	-87.15	-88.38	-89.42	-90.35	-87.8	-89	-88.90	-90	-87.67
50	48	49.87	49.41	49.41	48	49.89	49.87	49.41	48
70	-90.93	-91.36	-90.93	-92.05	-92.80	-93	-92.83	-91.74	-92.32

The current amplitude (dB) of phase A, phase B, phase C at fundamental (50 Hz), lower side band (30 Hz) and upper side band (70Hz) frequency during phase – ground fault at full load conditions are tabulated in Table 3.

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Table 3 Current amplitude in dB during phase - ground fault

FREQUENCY (HZ)	PHASE A – GROUND FAULT			PHASE B – GROUND FAULT			PHASE C – GROUND FAULT		
	I _a	I _b	I _c	I _a	I _b	I _c	I _a	I _b	I _c
30	-89.85	-94.33	-90.96	-90.82	-89.81	-94.42	-88.90	-90	-87.67
50	50.14	50.88	49.61	49.61	50.14	50.88	49.87	49.41	48
70	-97.89	-94.26	-93.47	-93.7	-98.6	-94.41	-92.83	-91.74	-92.32

The current spectrum waveform of short circuit fault (phase to phase and phase to ground) in each phase under full load condition is shown in Fig.4 and Fig.5.

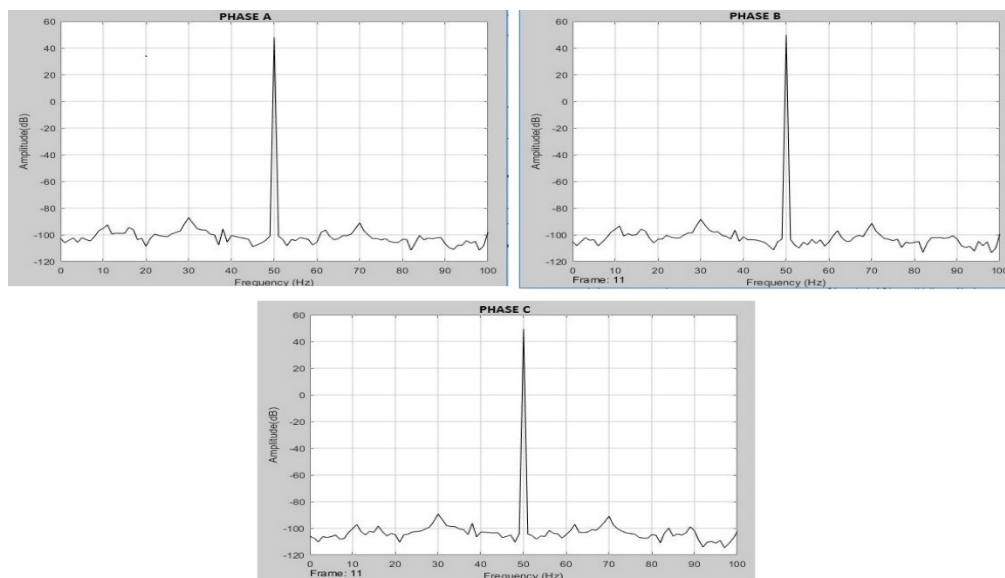


Fig.4. Current spectrum during phase - phase fault

The Current amplitude at fundamental (50Hz), lower side band (30 Hz) and upper side band (70 Hz) is visible as a peak value. This varies for different phase – phase and phase – ground faults. By using this characteristic of spectrum, faults are detected.

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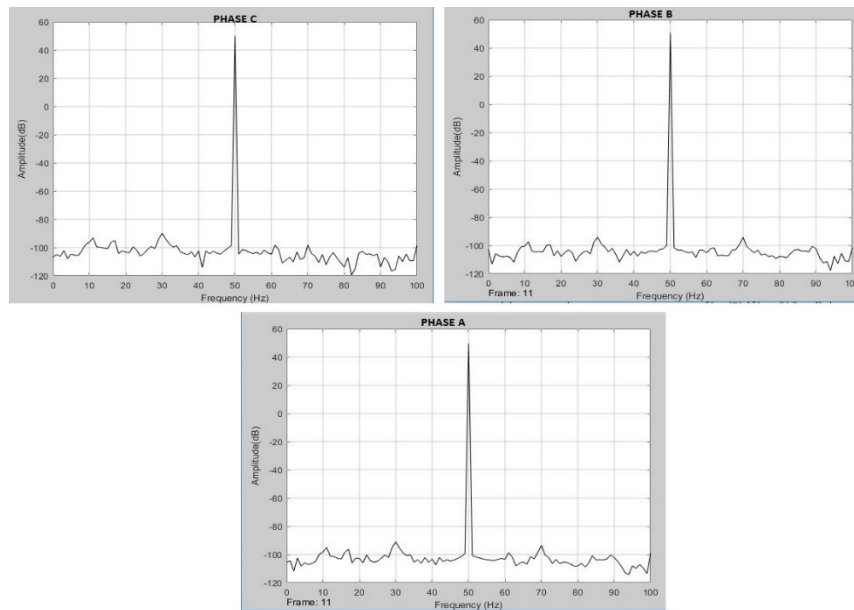


Fig.5. Current spectrum during phase - ground fault

IV. CONCLUSION

In this paper, three phase induction motor under healthy and short circuit fault condition is simulated using MATLAB - Simulink software. To detect the fault, Motor Current Signature Analysis is used. It helps in detection of various faults created in the motor as it can detect small changes in the parameters of the motor. The spectral analysis is based on detecting the frequency component of the stator current amplitude. These components are visible in the frequency spectrum of the stator current as side-bands to the fundamental peak. By using this characteristic of frequency spectrum, stator winding fault is detected. The detection of fault in earlier stage itself solves the shutdown problems and ensures safe working environment in continuous process industry.

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